Heat Production of Farm Livestock

by M. A. R. Kelley[1/]

Vitamins, amino-acids, carotene grams, and calories are terms familiar to nutritionists. To the layman they are more understandable when expressed as milk, meat, or carrots and to the engineer more useful when expressed in terms of pounds and B.t.u's. As a member of the Committee on Air Conditioning of Animal Buildings, I have endeavored to state our ignorance and to summarize the available data on the subject of Heat Production of Farm Livestock for the purpose of farm buildings design.

We as Agricultural Engineers have been fortunate in having the cooperation of Dr. Kriss[2/] and Dr. Mitchell[3/] who have been valuable aids in the work of our comittee for the past several years. We are glad to welcome the help of other nutritionists who have presented papers here today.

Some twenty years ago Dr. H. P. Armsby[4/] was asked to help us develop the basic data so essential to our work. Dr. Kriss was assigned to this task and published in 1921 the paper "Some Fundamentals of Stable Ventilation" (1)[5/]. This work constituted a landmark for the development of sound engineering practices in the proper ventilation of stables. Since that time other helpful studies have been made.

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4/ Dr. H. P. Armsby (deceased) at that time Director of Institute of Animal Nutrition of Pennsylvania State College.

5/ Reference is made by number (italic) to literature cited.

This paper summarizes pertinent available data. For convenience of use and conciseness of presentation, the estimated heat production for dairy cows and that for hogs are given in the form of curves, that for poultry in the form of a table--because of the importance of data for chicks as well as for mature birds. At present, because of the meager data available on horses and sheep, data on only the average animal is given. This will be helpful until further studies are made.

The graphs shown in figure 1 are based on data from Armsby & Kriss (1) and represent data for a cow under average feed and production.6/ Definite heat production from a cow of a known weight and production permits calculations for other weights by use of Rameaux's law. This law shows that the heat production varies as the 2/3 power of the body weight (Fig. 1.). More recently Kleiber (3) and Brody (5) have shown when applied to basal metabolism a remarkable relationship of this body weight to the 0.73 power, as applicable for a wide range of animals from that of mice to elephants. Our present use of this relationship as applied to metabolism under normal feeding, is limited because of the many factors which affect the heat production under practical conditions. Although it is of interest to note an average difference of 2.8 when compared with the curve figure 1, being slightly less for weights under 1200 pounds and a little higher for the heavier weights. Trial calculations for other farm animals shows a different ratio needed.

Requests are frequently made for information on the heat production of poultry. Since the original publication from which these data were obtained is now out of print (6) the information is condensed and the terms transposed and presented in Table 1.

6/ See table IV page 354 (1).

Figures 2 and 3 showing heat production for hogs as presented here are given for convenience of reference. More detailed information is found in a recent paper by Mitchell & Kelley (7).

The information now available on the heat production of horses appears inadequate for engineering design. In our tests (2) of two different barns and with heat units given by Armsby & Kriss used to estimate heat production, incompatible results were obtained when used for comparison of the cow stable with that of the horse stable in the same barn. Notwithstanding an estimate of the heat produced by a horse as but 60 percent of that by a cow, a higher stable temperature resulted. Brody et al (4) reveal that the basal and resting metabolism (lying at rest) for a horse of 1000 pounds weight is 30% above that of dairy cow of like weight. It appears no longer necessary to consider that the metabolism under normal conditions of feeding and activity of a horse would be less than that of a cow. If we assume that for the metabolism of the average horse the same ratio holds as that shown for basal metabolism by Brody, the average farm horse of 1350 pounds weight would produce 4510 Btu's per hour under normal metabolism. Such data would be more in agreement with results obtained under farm conditions and cited above (2).

Metabolism data for sheep are at present very meager and not readily available. Both Ritzman (9) and Mitchell (8) have made such studies but as yet their data have not been translated into engineering terms. In summary table 2 we have used Armsby and Kriss data for cows and sheep (1) and these will serve until additional studies make further refinement possible. Table 2 summarizes these data on the basis of average sizes of adult available.

Table 1. Hourly heat production of farm poultry and the water vaporized daily per bird. 1/

Body Weight	Bronze Turkey			Emden Geese			Pekin Ducks			Fowl W.P.R.		
		Production of			Production of			Production of			Production of	
	Age	Heat Hourly	Water Daily	Age	Heat Hourly	Water Daily	Age	Heat Hourly	Water Daily	Age	Heat Hourly	Water Daily
Pounds	Weeks	Btu.	Pounds	Weeks	Btu.	Pounds	Weeks	Btu.	Pounds	Weeks	Btu.	Pounds
0.077	---	---	---							0	1.65	.015
0.115	0	3.3	.030							---	---	---
0.126	---	---	---				0	2.88	.026	---	---	---
0.215	---	---	---	0	4.6	.05	---	---	---	---	---	---
0.5	3+	19.0	.18	1.7	18.7	.17	2.0	16.0	.15	4.6	13.6	.12
1.0	5+	28.1	.26	3.1	25.4	.24	3.2	22.3	.21	6.7	18.2	.17
1.5	---	---	---	3.8	30.0	.28	4.1	27.4	.25	8.9	22.3	.21
2.0	8	39.5	.37	4.4	33.9	.31	4.8	32.3	.30	10.7	26.3	.24
3.0	10-	47.4	.44	4.6	40.0	.37	6.2	41.6	.38	14.9	33.0	.31
4.0	11	54.0	.50	5.8	44.6	.41	7.5	49.6	.46	19.4	39.3	.36
5.0	12+	60.3	.56	6.9	50.9	.47	8.9	56.5	.52	25.4	46.2	.43
6.0	---	---	---	8.2	56.0	.52	11.1	62.0	.57	2/23.3	51.2	.47
7.0	15	72.2	.66	---	---	---	13.8	66.8	.61	2/	58.5	.54
8.0	---	---	---	11.1	64.8	.60	2/	67.3	.62			
9.0	---	---	---	----	---	---	2/	78.2	.72			
10.0	19	91.4	.84	14.5	73.7	.68						
12.0	---	---	---	18.7	81.5	.75						
15.0	---	118.8	1.09	27.5	92.7	.85						
18.0	---	---	---	45.4	102.0	.94						
20.0	52	132.4	1.21	---	108.1	1.00						
26.0	---	---	---	2/	133.1	1.22						
36.0	2/104	208.6	1.92									

1/ These data arranged from reference (6).

2/ Male birds.

Table 2. Heat Production of Average Livestock Under Ordinary Farm Conditions

Species	Live Weight	Heat Produced Hourly
	Pounds	Btu.
Dairy cow	1000	3000
Swine	300	1025
Fattening lamb	80 - 90	330
Turkey	15	119
Goose	12	81
Duck	6	62
Hen	5	46

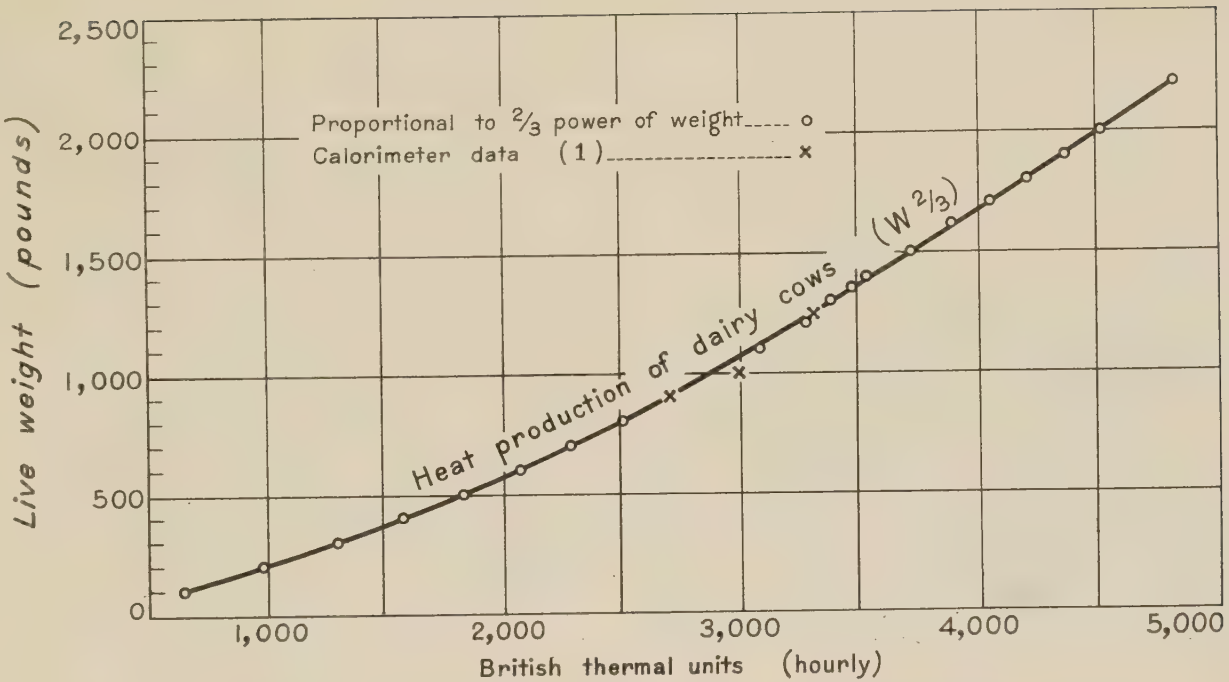

Figure 1. — Heat production of dairy cows

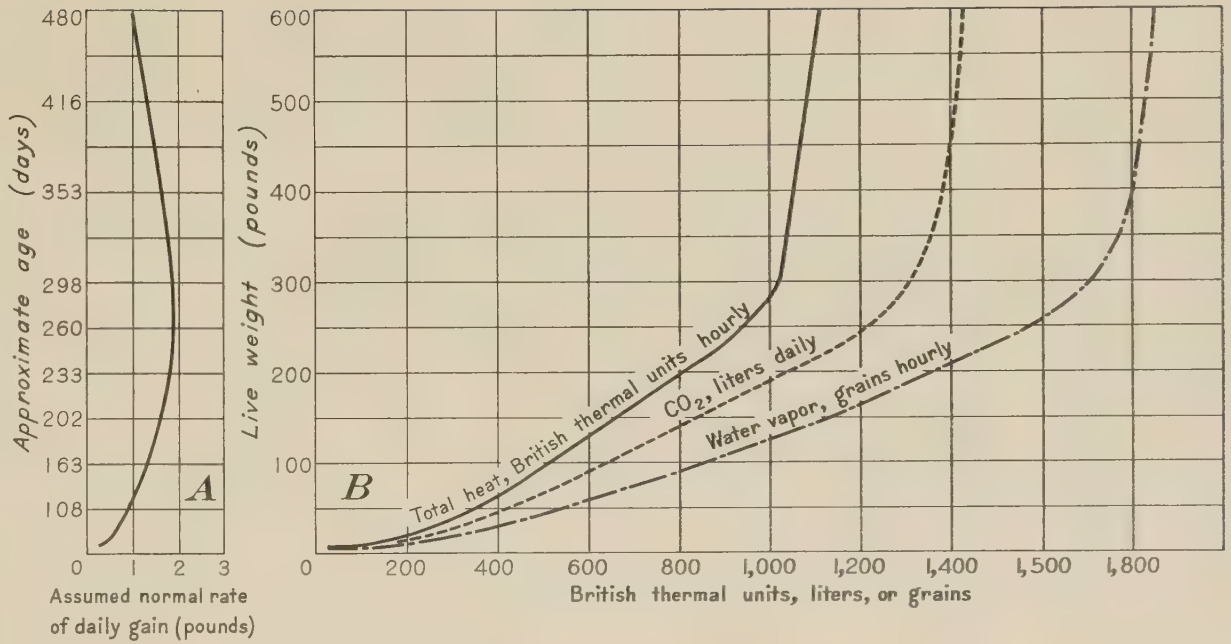

Figure 2.—*A*, Approximate normal growth of hogs; *B*, total hourly heat and water-vapor production and daily carbon dioxide production for hogs

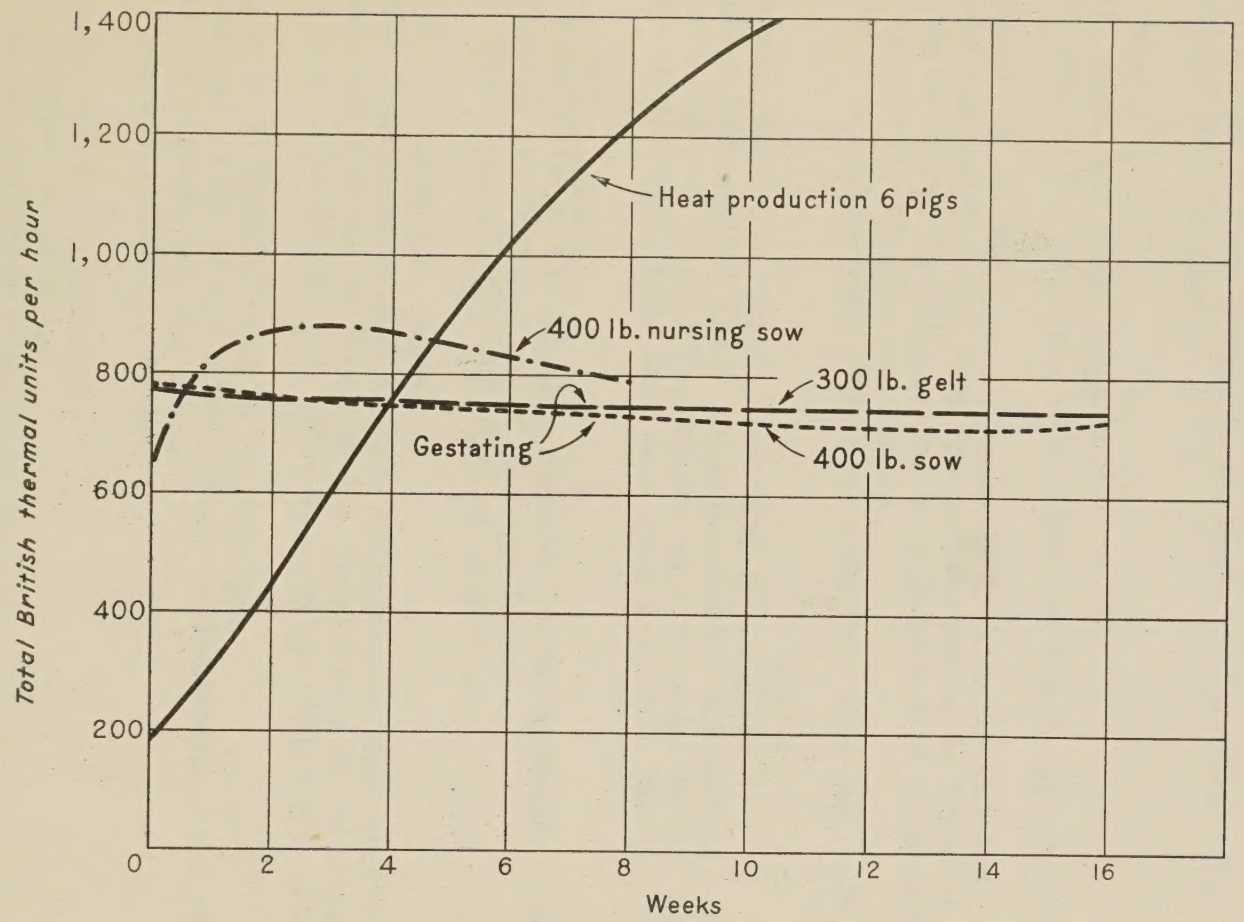

Figure 3.- Hourly heat production of gestating and nursing sows and a litter of six pigs

(1) Armsby, H. P. and Max Kriss
1921 Some Fundamentals of Stable Ventilation
Journal of Agr. Res. Vol XXI, No. 5 pp. 343-347

(2) Kelley, M.A.R.
1930 Ventilation of Farm Barns, U. S. Dept. of Agr. Tech. Bul. 187
73 pp. illus. (Out of print)

(3) Kleiber, Max
1935 Body, Size, and Metabolism
Hilgardia Vol. 6, No. 11, Jan. 1932, Univ. of Calif. pp. 316-353 illus.

(4) Brody, Samuel, W. C. Hall, A. C. Ragsdale & E. A. Trowbridge.
1932 Growth and Development with special reference to Domestic Animals XXIV
The Decline in Energy Metabolism Per Unit Weight with Increasing Age in Farm Animals, Laboratory Animals and Humans
University of Missouri, Agr. Exp. Sta. 1932 Res. Bul. Bul. 176 pp. (1-59) illus.

(5) Brody, Samuel, Robert C. Procter and Ural S. Ashworth
1934 Growth & Development XXXIV Basal Metabolism Endogenous Nitrogen, Creatinine & Neutral Sulphur Excretions as a function of the Body Weight
University of Missouri, Agr. Exp. Sta. 1934 Res. Bul. 220 pp. 1-40 illus.

(6) _____ & _____
1933 Estimated Data on the Energy, Gaseous and Water Metabolism of Poultry for Use in Planning the Ventilation of Poultry Houses
Jour. Agr. Res. Vol. 47: 735-348 (Out of print)

(7) Mitchell, H. H. and M.A.R. Kelley
1938, Energy Requirements of Swine and Estimates of Heat Production and Gaseous Exchange for use in Planning the Ventilation of Hog Houses
Jour. Agr. Res. Vol. 56, No. 11 June 1, 1938 pp. (811-830) illus.

(8) _____ & W. G. Kammlade and T. S. Hamilton
1928 A technical study of the maintenance and fattening lambs and their utilization of alfalfa hay and corn.
Ill. Sta. Bul. 314 (1928) pp. 29-60

(9) Ritzman E. G., and F. G. Benedict
1930 Energy Metabolism of Sheep
University of New Hampshire Experiment Sta.
Tech. Bul. 43 June 1930 pp. (1-23) illus.